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Maritime aerosol optical thickness measured by handheld sun photometers

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Abstract

For several years, the NASA SIMBIOS Project has collected, processed, and archived optical aerosol data from shipboard sun photometers. The calibration, processing, quality control, and archival methodology for handheld sun photometers are described here, along with their deployment statistics. Data processing has been standardized for all instruments by using identical calibration methods, ancillary data, and processing software. Statistical analysis reveals a dataset influenced by its temporal and geographic distribution, while multimodal histograms for aerosol optical thickness (AOT) and Ångström exponent reveal varied aerosol populations. A K-means unsupervised classification technique is used to separate these populations. This separation is validated by showing individual classes are more likely to be log-normally (for AOTs) or normally (for Ångström exponents) distributed than the dataset as a whole. Properties for each class are presented, along with the characteristics of each class by regional oceanic basin. Results also compare favorably with maritime aerosols measured by land-based AERONET Cimels in island sites, while providing data coverage in previously sparsely sampled regions. Aerosol models employed by SeaWiFS (Sea-Viewing Wide Field-of-View Sensor) also compare favorably with these ground based measurements.

Keywords: Maritime aerosols; Ångström exponent; Aerosol optical thickness; Sun photometer

1. Introduction

Since 1997, the NASA Sensor Inter-comparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project Office has maintained and deployed a pool of sun photometers for use in maritime regions. The SIMBIOS Project calibrates and maintains these instruments, while SIMBIOS Principal Investigators (PIs), at a number of institutions, deploy them on research cruises. Some SIMBIOS PIs also deploy their own instruments. The SIMBIOS Project then processes these data, performs quality control (QC), and archives the final result in the SeaWiFS Bio-Optical Archive and Storage System (SeaBASS) (Werdel and Bailey, 2002). SeaWiFS is Sea-Viewing Wide Field-of-View Sensor.

This paper is intended to be a macroscopic analysis of the entire dataset from two types of handheld sun photometers, each with five bands at visible and near-infrared (NIR) wavelengths. Data products from these instrument designs include aerosol optical thickness (AOT) at each wavelength

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and the Ångström exponent computed from the AOT spectra. The nature of these handheld instruments is such that sky almucanters (a scan of sky radiance measurements made at the same zenith angle as the sun but varying azimuth angles), and thus aerosol particle size distributions, cannot be computed as it is for automated Cimel sun photometers deployed by the NASA Aerosol Robotic Network (AERONET) (Holben et al., 1998). However, our data can compliment AERONET by sampling in previously inaccessible maritime regions. Calibration for the SIMBIOS Instrument Pool is achieved by comparing concurrent measurements between SIMBIOS and AERONET instruments at the AERONET rooftop facility at NASA's Goddard Space Flight Center in Greenbelt, MD.

The primary objective of the SIMBIOS Instrument Pool is to provide data for validation of aerosol products from SeaWiFS and other ocean color remote sensing satellites. The optical effect of aerosols upon the atmospheric correction of ocean color instruments is significant (Gordon & Wang, 1994). Comparisons of remotely sensed surface AOT from the SIMBIOS Instrument Pool to SeaWiFS AOT (a by-product of the atmospheric correction algorithm, Wang, 2000) can show the strengths and weaknesses of SeaWiFS atmospheric correction. This is particularly useful considering the volume of in situ bio-optical data gathered concurrently with aerosol data, providing the opportunity to validate other SeaWiFS (or other ocean color satellite) data products.

Surface measurements of column AOT can also be used to evaluate and refine aerosol models (Shettle & Fenn, 1979; Gordon & Wang, 1994) used in atmospheric correction. To do this, however, we must reduce the effects of data distribution upon dataset analysis. The SIMBIOS Instrument Pool was deployed on a variety of research cruises throughout the world's oceans. Heavily sampled regions include both East and West coasts of the United States and the Sea of Japan, as shown in Fig. 1. Data distribution is highly irregular, both temporally and geographically, so classification routines are utilized to split the data into groups of similar characteristics prior to analysis. This has paved the way to a proper comparison with data from AERONET and to SeaWiFS aerosol models.

7. Conclusions

The NASA SIMBIOS Project has been collecting, processing and archiving aerosol optical data from handheld sun photometers in maritime locations since 1997, and to date has collected nearly 11,000 individual measurements from 145 individual cruises. This paper describes methods used by the SIMBIOS Project to calibrate instruments, process their data, remove erroneous measurements, perform quality control, and archive the results.

Maps and statistical analysis of the dataset as a whole reveal that it is heavily dependent upon its spatial and temporal collection characteristics. While about a third of the data were captured more than 500 km from a major landmass, much of the data were collected in coastal North America, East Asia, and Europe. Likewise, frequency histograms of AOT and Ångström exponent show several peaks, indicating that several different populations of aerosols were measured.

To remove data collection characteristics from an overall analysis, a semi-empirical K-means unsupervised classification technique was used to separate the data into optically unique populations. This was validated by proving (with the KS goodness of fit test) that individual classes are more likely to be log-normally (for AOT) or normally (for Ångström exponents) distributed than the dataset as a whole. This proof also reinforces the claim by several others (Ignatov & Stowe, 2002; O'Neill et al., 2000) that AOT values are log-normally distributed and should be treated appropriately.

Finally, properties for each class were presented, along with the characteristics of each class by regional oceanic basin. Ångström exponents from class 2 maritime data compare well with SeaWiFS aerosol models, and favorably with maritime aerosols measured by land-based AERONET Cimels in island sites. This further validates the SIMBIOS sun photometer dataset, which is calibrated with respect to AERONET Cimels. It is important to note, however, that a definitive comparison between Ångström exponents from maritime aerosols is difficult due to the large uncertainties associated with computing Ångström exponents in low aerosol optical thicknesses. In any case, the dataset adds to the scientific body of knowledge by extending sampling to previously remote maritime regions.

News and updates about the SIMBIOS sun photometer instrument pool can be found at http://simbios.gsfc.nasa.gov/Sunphotometers.

SIMBIOS data are available, with some restrictions, at http://seabass.gsfc.nasa.gov.